

FIGURE 4. Range of human motion

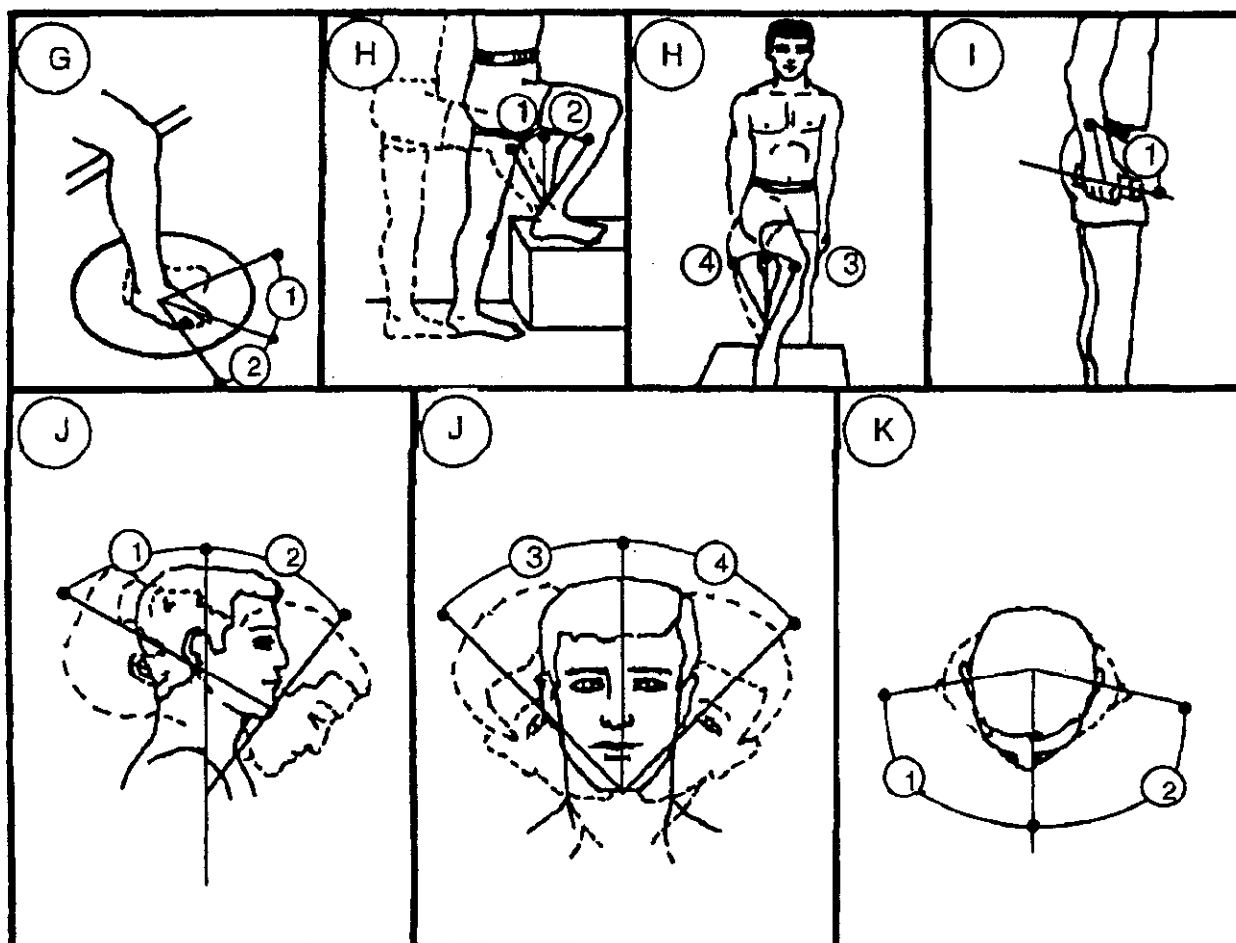


FIGURE 4. Range of human motion - continued

TABLE II. Range of human motion - continued<sup>1</sup>

Body Member	Movement	Lower Limit (degrees)	Average (degrees)	Upper Limit (degrees)
G. Foot Rotation	1. Medial	23	35	47
	2. Lateral	31	43	55
H. Ankle	1. Extension	26	38	50
	2. Flexion	28	35	42
	3. Adduction	15	24	33
	4. Abduction	16	23	30
I. Grip Angle		95	102	109
J. Neck Flexion	1. Dorsal (back)	44	61	88
	2. Ventral (forward)	48	60	72
	3. Right	34	41	48
	4. Left	34	41	48
K. Neck Rotation	1. Right	65	79	93
	2. Left	65	79	93

<sup>1</sup>These values are based on the nude body. The ranges are larger than they would be for clothed personnel.

Flexion: Bending or decreasing the angle between parts of the body.

Extension: Straightening or increasing the angle between parts of the body.

Adduction: Moving toward the midline of the body.

Abduction: Moving away from the midline of the body.

Medial Rotation: Turning toward the midplane of the body.

Lateral Rotation: Turning away from the midplane of the body.

Pronation: Rotation of the palm of the hand downward.

Supination: Rotation of the palm of the hand upward.

### A5.3. Push and pull forces.

A5.3.1. Horizontal. Manual horizontal push and pull forces required to be applied or to be sustained over a short period of time shall not exceed the values of Table III, as applicable, or those given in Figure 6, if more appropriate to the force and movement characteristics of the task.

**TABLE III. Horizontal push and pull forces exerable intermittently  
or for short periods of time**

HORIZONTAL FORCE <sup>1</sup>	APPLIED WITH <sup>2</sup>	CONDITION ( $\mu$ = Coefficient of Friction)
100N (25 lb) push or pull	both hands or one shoulder or the back	Low traction: $0.2 < \mu < 0.3$
200N (45 lb) push or pull	both hands or one shoulder or the back	Medium traction: $\mu \sim 0.6$
300N (70 lb) push or pull	both hands or one shoulder or the back	High traction: $\mu > 0.9$

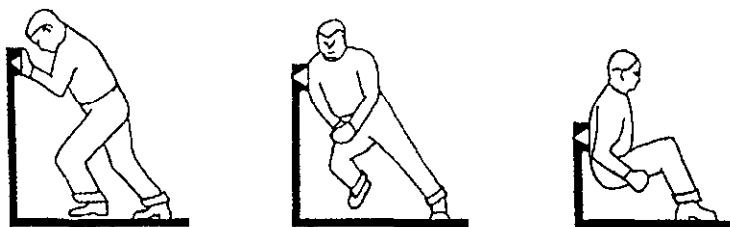
<sup>1</sup>May be doubled for two and tripled for three operators pushing simultaneously. For the fourth and each additional operator, not more than 75% of their push capability should be added.

<sup>2</sup>See figure 4 for examples.

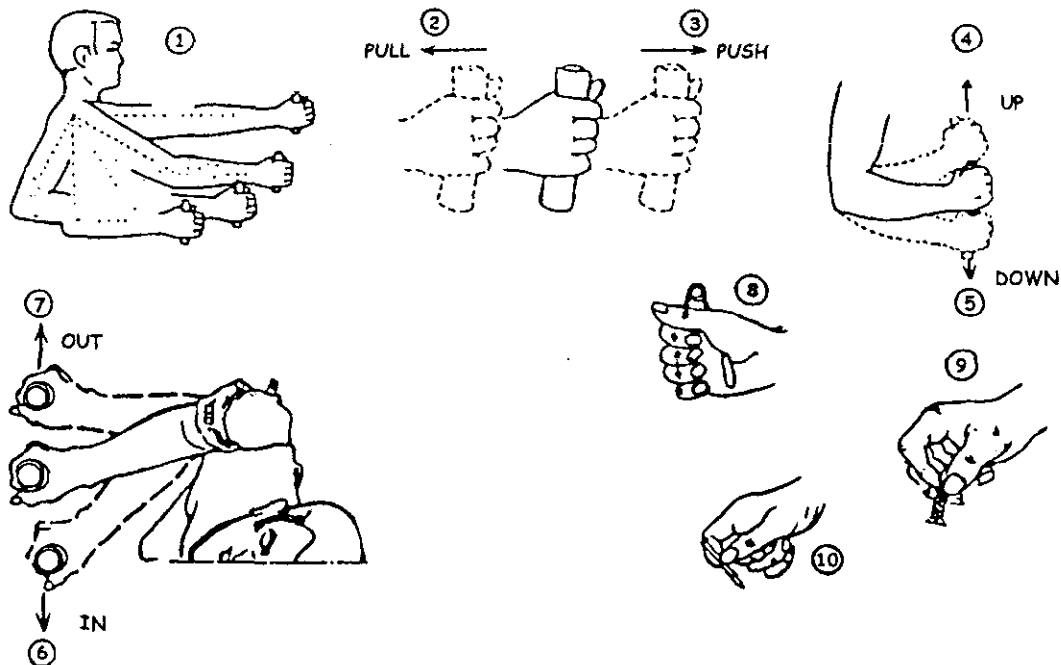
Note: Values are predicated upon a suitable surface for force exertion, i.e., a vertical, rough surface, approximately 40 cm (16 in) wide, and 510 - 127 cm (20 - 50 in) above the floor to allow force application with the hands, the shoulder, or the back.

This table is an excerpt of MIL-STD-1472, Table XXIV. The data are normally considered to apply to the male population only. Here they are applied to the female population as well, on the presumption that females meeting the strength requirements for MOS 44B, Metal Worker, will of necessity have a body mass at least equal to that of the 5<sup>th</sup> percentile male in the general population.

LOW/MEDIUM/HIGH TRACTION



**FIGURE 5. Examples of push force conditions for Table II**



ARM STRENGTH (N)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L*	R*	L	R	L	R	L	R	L	R	L	R
180	222	231	187	222	40	62	58	76	58	89	36	62
150	187	249	133	187	67	80	80	89	67	89	36	67
120	151	187	116	160	76	107	93	116	89	98	45	67
90	142	165	98	160	76	89	93	116	71	80	45	71
60	116	107	98	151	67	89	80	89	76	89	53	76
HAND, AND THUMB-FINGER STRENGTH (N)												
	(8)		(9)		(10)							
	HAND GRIP		THUMB-FINGER GRIP (PALMER)		THUMB-FINGER GRIP (TIPS)							
	L	R										
MOMENTARY HOLD	250	250	60		60							
SUSTAINED HOLD	145	155	35		35							

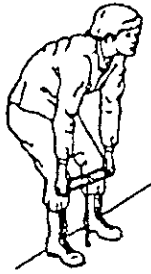
\* L = LEFT; R = RIGHT

FIGURE 6. Arm, hand and thumb-finger strength (5<sup>th</sup> percentile male data)

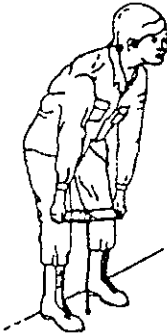
A5.3.2. Vertical. Manual vertical push and pull forces required shall not exceed the applicable fifth percentile peak or mean force values cited for men in Table IV, or those given in Figure 6, if more appropriate to the force and movement characteristics of the task.

Table IV. Static Muscle Strength Data

Strength measurements	Percentile Values in Newtons (Pounds)			
	5 <sup>th</sup> Percentile		95 <sup>th</sup> Percentile	
	Men	Women	Men	Women
(see Figure 6)				
A Standing two-handed pull:				
38 cm level				
Mean force	738(166)	331(74)	1354(304)	818(184)
Peak force	845(190)	397(89)	1437(323)	888(200)
B Standing two-handed pull:				
50 cm level				
Mean force	758(170)	326(73)	1342(302)	841(189)
Peak force	831(187)	374(84)	1442(324)	905(203)
C Standing two-handed pull:				
100 cm level				
Mean force	444(100)	185(42)	921(209)	443(100)
Peak force	504(113)	218(49)	988(222)	493(111)
D Standing two-handed push:				
150 cm level				
Mean force	409(92)	153(34)	1017(229)	380(85)
Peak force	473(106)	188(42)	1094(246)	430(97)
E Standing one-handed pull:				
100 cm level				
Mean force	215(48)	103(23)	628(141)	284(64)
Peak force	259(58)	132(30)	724(163)	322(72)



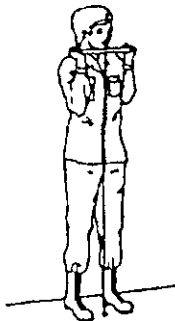
- A. STANDING TWO-HANDED PULL: 38 cm (15") LEVEL  
STANDING WITH FEET 45 cm (18") APART AND KNEES BENT. BENDING AT WAIST, GRASPING BOTH SIDES, OF 45 cm (18") LONG HANDLE LOCATED DIRECTLY IN FRONT, 38 cm (15") ABOVE STANDING SURFACE, AND PULLING, USING PRIMARILY ARMS, SHOULDERS AND LEGS.



- B. STANDING TWO-HANDED PULL: 50 cm (20") LEVEL  
STANDING WITH FEET 45 cm (18") APART AND KNEES STRAIGHT. BENDING AT WAIST, GRASPING BOTH SIDES OF 45 cm (18") LONG HANDLE LOCATED DIRECTLY IN FRONT, 50 cm (20") ABOVE STANDING SURFACE, AND PULLING, USING PRIMARILY ARMS AND SHOULDERS.



- C. STANDING TWO-HANDED PULL: 100 cm (39") LEVEL  
STANDING ERECT WITH FEET 45 cm (18") APART, GRASPING BOTH SIDES OF 45 cm (18") LONG HANDLE LOCATED DIRECTLY IN FRONT, 100 cm (39") ABOVE STANDING SURFACE, AND PULLING, USING THE ARMS.



- D. STANDING TWO-HANDED PUSH: 150 cm (59") LEVEL  
STANDING ERECT WITH FEET 45 cm (18") APART, GRASPING FROM BELOW, BOTH SIDES OF 45 cm (18") LONG HANDLE LOCATED DIRECTLY IN FRONT, 150 cm (59") ABOVE STANDING SURFACE. PUSHING UPWARD USING ARMS AND SHOULDERS.



- E. STANDING ONE-HANDED PULL: 100 cm (39") LEVEL  
STANDING ERECT WITH FEET 15 cm (6") APART, DOMINANT HAND GRASPING UNDERSIDE OF D-RING LOCATED DIRECTLY TO THE SIDE, 100 cm (39") ABOVE STANDING SURFACE. PULLING UPWARD WHILE KEEPING SHOULDER SQUARE AND OTHER ARM RELAXED AT SIDE.

FIGURE 7. Static muscle strength data

#### A5.4. Weight.

A5.4.1. Lifting limits. The weight limits in Table V, conditions A and B, shall be used as maximum values in determining the design weight of items requiring one person lifting with two hands. The weight limits in Table V plus 18 kg (40 lb) shall be used as the maximum values in determining the design weight of items requiring two person lifting, provided the load is uniformly distributed between the two lifters. If the weight of the load is not uniformly distributed, the weight limit of Table V applies to the heavier lift point. Where three or more persons are lifting simultaneously, not more than 14 kg (30 lb) may be added for each additional lifter, provided that the object lifted is sufficiently large that the lifters do not interfere with one another while lifting. Where *it is not possible to define the height to which an object will be lifted in operational use*, the limit wherein the object is lifted to shoulder height shall be used rather than the more permissive bench height value. The values in Table V are applicable to objects with or without handles.

TABLE V. Design weight limits

HANDLING FUNCTION	POPULATION*
	Male and Female
A. Lift an object from the floor and place it on a surface not greater than 152 cm (5 ft) above the floor.	36.4 kg (80 lb)
B. Lift an object from the floor and place it on a surface not greater than 91 cm (3 ft) above the floor.	53.6 kg (118 lb)
C. Carry an object 7.6 m (25 ft) or less.	53.6 kg (118 lb)

\* Data from MIL-STD-1472 adjusted to reflect the physical requirements for Metal Workers, Military Occupational Specialty (MOS) 44B, in accordance with MIL-STD-1472 paragraph 1.4 and Army Regulation 611-201.

A5.4.2. Load size. The maximum permissible weight lift limits in Table V apply to an object with uniform mass distribution and a compact size not exceeding 46 cm (18 in) high, 46 cm (18 in) wide, and 30 cm (12 in) deep (away from the lifter). This places the hand holds at half the depth, or 15 cm (6 in) away from the body. If the depth of the object exceeds 61 cm (24 in) the permissible weight shall be reduced by 33 percent. If the depth of the object exceeds 91 cm (36 in), the permissible weight shall be reduced by 50 percent. If the depth of the object exceeds 122 cm (48 in), the permissible weight shall be reduced by 66 percent.



A5.4.3. Obstacles. The values in Table V assume that there are no obstacles between the person lifting and the shelf, table, bench or other surface on which the object is to be placed. Where a lower protruding shelf or other obstacle limits the lifter's approach to the desired surface, the weight limit of the object shall be reduced by 33 percent.

A5.4.4. Carrying limits. The weight limit in Table V condition C shall be used as the maximum value in determining the design weight of items requiring one person carrying of objects a distance of up to 7.6 m (25 ft). The maximum permissible weight for carrying an object with a handle on top, such as a tool box, which usually is carried at the side with one hand, is 36 kg (80 lbs). The one-person weight carrying limit plus 18 kg (40 lbs) shall be used as the maximum value in determining the design weight of items requiring two-person carrying, provided the load is uniformly distributed between the two carriers. Where three or more persons are carrying a load together, not more than 14 kg (30 lbs) may be added for each additional person, provided that the object is sufficiently large that the workers do not interfere with one another while carrying the load. In all cases involving carrying, it is assumed that the object is first lifted from the floor, carried a distance of 7.6 m (25 ft) or less, and placed on the floor or on another surface not higher than 91 cm (36 in). If the final lift is to a higher height, the 152 cm (5 ft) lift height applies as the more limiting case.

A5.4.5. Object carry size. The reduction formula expressed in paragraph B5.3.2 shall be applied to size of objects to be carried in the same manner as for load size.

A5.4.6. Labeling. Items weighing more than 18 kg (40 lb) shall be prominently labeled with the weight of the object. Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled.

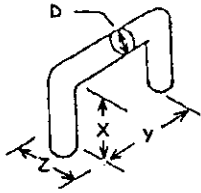
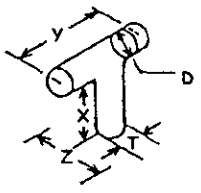
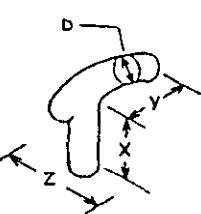
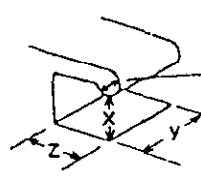
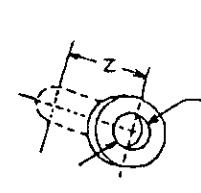
#### A5.5. Handles and grasp areas.

A5.5.1. General. All items designed to be carried or removed and replaced shall be provided with handles or other suitable means for grasping, handling, and carrying by a gloved or mittened hand. Items requiring handling should be provided with not less than two handles or one handle and one grasp area. Items weighing less than 4.5 kg (10 lb) whose form factor permits them to be handled easily shall be exempt from this requirement.

A5.5.2. Location. Whenever possible, handles, grasp areas, or hoist points shall be located above the center of gravity and in a manner to preclude uncontrolled swinging or tilting when lifted. They shall be located to provide at least 5 cm (2 in) of clearance from obstructions during handling. The location of handles shall not interfere with installing, removing, operating, or maintaining the equipment.

A5.5.3. Nonfixed handles. Nonfixed handles (e.g., hinged or fold-out) shall have a stop position for holding the handle perpendicular to the surface on which it is mounted and shall be capable of being placed into carrying position by one hand (where appropriate, by a gloved or mittened hand).

A5.5.4. Grasp surface. Where an item's installation requires that its bottom surface be used as a handhold during removal or installation, a nonslip grasp surface (e.g., grooved, knurled, or frictional) shall be provided.

ILLUSTRATION	TYPE OF HANDLE	DIMENSIONS IN mm (in inches)								
		'Bare Hand)			(Gloved Hand)			(Mittened Hand)		
		X	Y	Z	X	Y	Z	X	Y	Z
	Two-finger bar	32 (1-1/4)	65 (2-1/2)	75 (3)	38 (1-1/2)	75 (3)	75 (3)	Not Applicable		
	One-hand bar	48 (1-7/8)	111 (4-3/8)	75 (3)	50 (2)	125 (5)	100 (4)	75 (3)	135 (5-1/4)	150 (6)
	Two-hand bar	48 (1-7/8)	215 (8-1/2)	75 (3)	50 (2)	270 (10-1/2)	100 (4)	75 (3)	280 (11)	150 (6)
	T-bar	38 (1-1/2)	100 (4)	75 (3)	50 (2)	115 (4-1/2)	100 (4)	Not Applicable		
	J-bar	50 (2)	100 (4)	75 (3)	50 (2)	115 (4-1/2)	100 (4)	75 (3)	125 (5)	150 (6)
	Two-finger recess	32 (1-1/4)	65 (2-1/2)	50 (2)	38 (1-1/2)	75 (3)	50 (2)	Not Applicable		
	One-hand recess	50 (2)	110 (4-1/4)	90 (3-1/2)	90 (3-1/2)	135 (5-1/4)	100 (4)	90 (3-1/2)	135 (5-1/4)	125 (5)
	Finger-tip recess	19 (3/4)	-	13 (1/2)	25 (1)	-	19 (3/4)	Not Applicable		
	One-finger recess	32 (1-1/4)	-	50 (2)	38 (1-1/2)	-	50 (2)	Not Applicable		

Curvature of Handle or Edge

(DOES NOT PRECLUDE USE OF OVAL HANDLES)

Weight of Item

Up to 6.8 kg (up to 15 lbs)

6.8 to 9.0 kg (15 to 20 lbs)

9.0 to 18 kg (20 to 40 lbs)

Over 18 kg (over 40 lbs)

T-bar Post

Minimum Diameter

D - 6 mm (1/4 in)

D - 13 mm (1/2 in)

D - 19 mm (3/4 in)

D - 25 mm (1 in)

T - 13mm (1/2 in)

Gripping efficiency is best if finger can curl around handle or edge to any angle of  $\frac{2}{3} \pi$  rad (120°) or more.

FIGURE 8. Minimum handle dimensions

A5.5.5. Handle dimensions. Handles which are to be used with mittened, gloved, or ungloved hands shall equal or exceed the minimum applicable dimensions shown in Figure 8.

A5.5.6. Handle and grasp area force requirements. Force requirements to operate handle and grasp areas shall not exceed the values in Figure 6.

A5.5.7. Handle material. Handles or grasp areas used with bare hands should have surfaces that are not thermally (see thermal contact hazards paragraph) or electrically conductive. The surface shall be sufficiently hard to prevent embedding of grit and grime during normal use.

A5.6. Vibration. Equipment oscillations should not impair human performance with respect to control manipulations or the readability of numerals or letters. Equipment vibrations in the range of 1 to 4 Hz having an acceleration greater than 8 feet per second (rms) should be avoided.

#### A5.7. Storage.

##### A5.7.1. General.

A5.7.1.1. Standardization. Standard containers shall be used whenever practicable and should meet the human engineering criteria herein.

A5.7.1.2. Ease of replacement. Equipment shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations. (See B5.3.)

A5.7.1.3. Clothing constraints. Equipment shall be capable of being removed and replaced by personnel wearing personal protective and special purpose clothing and equipment, including NBC protective clothing in an NBC contaminated environment.

A5.7.1.4. Removal. Stored items should be removable along a straight or slightly curved line, rather than through an angle.

A5.7.1.5. Limit stops. Limit stops shall be provided on drawers. Drawers shall be self-locking in the retracted and extended positions. The limit stop design shall permit convenient overriding of stops for drawer removal.

A5.7.1.6. Covers or panels. Removal of any stored item shall require opening or removing a minimum number of covers.

##### A5.7.2. Mounting of items within units.

A5.7.2.1. Similar items. Similar items and containers shall utilize a common mounting design and orientation within the unit. Similar items and containers shall be made distinguishable by labeling, color coding, or marking.

A5.7.2.2. Delicate items. Components susceptible to personnel-induced damage (e.g., rough handling, abrasion, or contamination) shall be clearly identified and guarded from abuse both physically and procedurally.

##### A5.7.3. Accessibility.

A5.7.3.1. Structural members. Structural members or permanently installed equipment shall not visually or physically obstruct removal and replacement of stored equipment. Equipment restraining devices shall be directly visible and physically accessible to the user.

A5.7.3.2. Large items. Large items which are difficult to remove shall be so mounted that they will not prevent convenient access to other items.

A5.7.3.3. Relative accessibility. Items requiring most frequent access shall be most accessible.

#### A5.7.4. Storage containers.

A5.7.4.1. Securing of covers. It shall be obvious when a storage container door or lid is not secured, even though it may be in place.

A5.7.4.2. Instructions. If the method of opening a storage container is not obvious from the construction of the container itself, instructions shall be permanently displayed on the outside of the container. Instructions shall consist of simple symbols such as arrows or simple words such as "push" or "push and turn."

A5.7.4.3. Clearance. Bulkheads, brackets, and other equipment shall not obstruct visual or physical access for removal, replacement, or opening of storage containers. Covers, doors or panels which must be opened to remove or replace equipment and supplies shall be visually and physically accessible to the user.

A5.7.4.4. Self-supporting covers. Hinged lids and doors shall be self-supporting in the open position. The cover in the open position shall not obstruct required visual or physical access to the stored equipment. Self-supporting covers should be capable of being opened and closed with one hand.

A5.7.4.5. Labeling. Each storage container should be labeled with nomenclature for the items it contains. Accesses shall be labeled with warning signs disclosing any hazards existing within the storage area and prescribing precautions. Opening or removing an access cover shall not remove or visually obstruct any hazard warning.

A5.7.4.6. Rounding. Cover and access edges shall be rounded (See safety paragraph on edge rounding) to preclude hand injury or clothing damage.

#### A5.7.5. Physical access.

A5.7.5.1. Arm and hand access. Openings provided for access to stored equipment shall be sized to permit the required handling and shall provide an adequate view of the item being manipulated. All blind arm and hand access shall require approval of the procuring activity.

A5.7.5.1.1. Opening covers. Access covers shall be equipped with grasp areas or other means for opening them. Covers shall accommodate handwear or special clothing that may be worn by the maintainer.

A5.7.5.1.2. Reach access dimensions and shape. The dimensions of access openings shall be not less than those shown in Figure 9. Allowance shall be made for the clearance of the operator's hand, applicable handwear, and clothing. Access shape shall provide clearance for the equipment (including its protuberances, attachments and handles) that the user must pass through the opening, appropriate body parts, and tools.

A5.7.5.1.3. Guarding hazardous conditions. If a hazardous condition exists behind the access, the presence of the hazard shall be noted on the cover such that it remains visible when the access is open. Also see B5.6.4.5.

A5.7.5.1.4. Type of opening. Where equipment storage is required, the following practices shall be followed in order of preference: a. An opening with no cover unless this is likely to degrade system performance, security, safety, or NBC contamination survivability. b. A hand-operated (sliding or hinged) lid or door. c. A hand-operated latched lid.

A5.7.5.2. Access cover attachment. Covers shall be secured with the fewest number of simplest-to-operate latches practicable. Latches shall be operable by hand. Small, removable covers shall be attached to the structure or otherwise retained to prevent loss.

A5.7.6. Attachments. Connected appurtenances, accessories, cables, hoses, and similar items shall not interfere with removing, replacing, or carrying a stored item. If such connected appurtenances interfere with these tasks, they shall be easily removed or disconnected from the equipment before handling. Easy disconnect shall consist of hand operable quick disconnect or standard hand tool operable disconnects in that order of preference.

## MINIMAL TWO-HAND ACCESS OPENINGS WITHOUT VISUAL ACCESS

### Reaching with both hands to depth of 150 to 490mm:

Light clothing:	Width:	200mm or the depth of reach*
	Height:	125mm
Arctic clothing:	Width:	150mm plus 3/4 the depth of reach
	Height:	180mm

### Reaching full arm's length (to shoulders) with both arms:

Width:	600mm
Height:	125mm

### Inserting box grasped by handles on the front:

13mm clearance around box, assuming adequate clearance around handles

### Inserting box with hands on the sides:

Light clothing:	Width:	Box plus 115mm
	‡ Height:	125mm or 13mm around box*
Arctic clothing:	Width:	Box plus 180mm
	‡ Height:	215mm or 15mm around box*

\*Whichever is larger.

‡If hands curl around bottom, allow an extra 38mm for light clothing, 75mm for arctic clothing.

## MINIMAL ONE-HAND ACCESS OPENINGS WITHOUT VISUAL ACCESS

### Empty hand, to wrist:

Bare hand, rolled:	95mm	sq or dia
Bare hand, flat:	55mm	x 100mm or 100mm dia
Glove or mitten:	100mm	x 150mm or 150mm dia
Arctic mitten:	125mm	x 165mm or 165mm dia

### Clenched hand, to wrist:

Bare hand:	95mm	x 125mm or 125mm dia
Glove or mitten:	115mm	x 150mm or 150mm dia
Arctic mitten:	180mm	x 215mm or 215mm dia

### Hand plus 1" dia object, to wrist:

Bare hand:	95mm	sq or dia
Gloved hand:	150mm	sq or dia
Arctic mitten:	180mm	sq or dia

### Hand plus object over 1" in dia, to wrist:

Bare hand:	45mm clearance around object
Glove or mitten:	65mm clearance around object
Arctic mitten:	90mm clearance around object

### Arm to elbow:

Light clothing:	100mm x 115mm
Arctic clothing:	180mm sq or dia
With object:	Clearances as above

### Arm to shoulder:

Light clothing:	125mm sq or dia
Arctic clothing:	215mm sq or dia
With object:	Clearances as above

## MINIMAL FINGER ACCESS TO FIRST JOINT

### Push button access:

Bare hand:	32mm dia
Gloved hand:	38mm dia

### Two finger twist access:

Bare hand:	object plus 50mm
Gloved hand:	object plus 65mm

FIGURE 9. Arm and hand access dimensions

## A5.8. Design for maintainer.

### A5.8.1. General.

A5.8.1.1. Standardization. Standard parts shall be used whenever practicable and should meet the human engineering criteria herein.

A5.8.1.2. Special tools. Special tools shall be used only when common hand tools cannot be used, when they provide significant advantage over common hand tools, or where required by security considerations. Special tools required for operational adjustment maintenance should be securely mounted within the equipment in a readily accessible location.

A5.8.1.3. Ease of replacement. Equipment shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations. (See B5.3.)

A5.8.1.4. Assembly and disassembly. Equipment shall be capable of being assembled and disassembled in its operational environment by a minimum number of trained personnel wearing clothing appropriate to the operating environment specified for the system maintenance concept.

A5.8.1.5. Clothing constraints. Equipment shall be capable of being removed, replaced, and repaired by personnel wearing personal protective and special purpose clothing and equipment appropriate to the maintenance concept, including NBC protective clothing in an NBC contaminated environment.

A5.8.1.6. Error-proof design. Improper mounting and installation (including interchange of items of a same or similar form that are not in fact functionally interchangeable) shall be prevented by physical measures to ensure proper mounting of items (e.g., alignment devices).

### A5.8.2. Mounting of items within units.

A5.8.2.1. Similar items. Similar items shall utilize a common mounting design and orientation within the unit. This mounting design shall preclude interchange of items which are not functionally interchangeable. Similar items which are not functionally interchangeable shall be made distinguishable by labeling, color coding, or marking to prevent unwanted substitution.

A5.8.2.2. Delicate items. Components susceptible to maintenance-induced damage e.g., rough handling, abrasion, contamination) shall be clearly identified and guarded from abuse both physically and procedurally.

### A5.8.3. Accessibility.

A5.8.3.1. Structural members. Structural members or permanently installed equipment shall not visually or physically obstruct adjustment, servicing, removal of replaceable equipment, or other required maintenance tasks. Panels, cases, and covers removed to access equipment shall have the same access requirements as replaceable equipment. Mounting provisions shall be directly visible and physically accessible to the maintainers.

A5.8.3.2. Large items. Large items which are difficult to remove shall be so mounted that they will not prevent convenient access to other items.

A5.8.3.3. Use of tools and test equipment. Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

A5.8.3.4. Relative accessibility. Items requiring most frequent access shall be most accessible.

A5.8.3.5. High-failure-rate items. High-failure-rate items should be accessible for replacement without moving non-failed items. Mechanical replacement items shall be removable with common hand tools and simple handling equipment.

#### A5.8.4. Lubrication.

A5.8.4.1. General. Configuration of equipment requiring lubrication shall permit lubrication and, as applicable, checking of lubricant reservoir levels without disassembly. Extended fittings shall be provided to lubricant ports that would not otherwise be readily accessible or visible.

A5.8.4.2. Labeling. Where lubrication is required, the type of lubricant to be used and the frequency of lubrication shall be specified by a label mounted at or near the lube port or grease fitting. A lubrication chart of permanent construction shall be mounted at the operator station of the equipment; individual labels shall not be required when the equipment has only one type of fitting and uses only one type of lubricant.

#### A5.8.5. Covers.

A5.8.5.1. Case and cover mounting. Cover or shield holes shall be large enough for mounting screw clearance without perfect case alignment.

A5.8.5.2. Securing of covers. It shall be made obvious when a cover is not secured, even though it may be in place.

A5.8.5.3. Instructions. If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover. Instructions shall consist of simple symbols such as arrows or simple words such as "push" or "push and turn."

A5.8.5.4. Clearance. Bulkheads, brackets, and other equipment shall not obstruct visual or physical access for removal or opening of covers on equipment within which work must be performed in the installed condition. Covers, doors or panels which must be opened to perform on-site maintenance shall be visually and physically accessible to the maintainers.

#### A5.8.6. Access openings and covers.

A5.8.6.1. Application. An access shall be provided if frequent maintenance would otherwise require removing a case or covering, or dismantling an item of equipment.

A5.8.6.2. Self-supporting covers. Hinged access covers that are not completely removable shall be self-supporting in the open position. The cover in the open position shall not obstruct required visual or physical access to the equipment being maintained or to related equipment during maintenance. Self-supporting covers should be capable of being opened and closed with one hand.

A5.8.6.3. Labeling. Each access should be labeled with nomenclature for items visible or accessible through it. Accesses shall be labeled with warning signs, disclosing any hazards existing beyond the access and prescribing precautions. Opening or removing an access cover shall not remove or visually obstruct any hazard warning. If instructions applying to a covered item appear on a hinged door, the lettering shall be oriented to be read when the door is open.



A5.8.6.4. Rounding. Cover and access edges shall be rounded (See safety paragraph on edge rounding) to preclude hand injury or clothing damage.

#### A5.8.7. Physical access.

A5.8.7.1. Arm and hand access. Openings provided for access to interior equipment shall be sized to permit the required adjustment or handling and shall provide an adequate view of the item being manipulated. All blind arm and hand access shall require approval of the procuring activity.

A5.8.7.1.1. Opening covers. Access covers shall be equipped with grasp areas or other means for opening them. Covers shall accommodate handwear or special clothing that may be worn by the maintainer.

A5.8.7.1.2. Reach access dimensions and shape. The dimensions of access openings shall be not less than those shown in Figure 9. Allowance shall be made for the clearance of the operator's hand, applicable handwear, and clothing. Access shape shall provide clearance for the equipment (including its protuberances, attachments and handles) that the maintainer must reach through the opening, appropriate body parts, and tools.

A5.8.7.1.3. Tool access dimensions. Access openings shall be large enough to operate tools required for maintenance of the equipment reached through the access.

A5.8.7.1.4. Guarding hazardous conditions. If a hazardous condition (such as exposed, high voltage conductors) exists behind the access, the physical barrier over the access shall be equipped with an interlock that will de-energize the hazardous equipment when the barrier is open or removed. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover such that it remains visible when the access is open. Also see 5.9.9.3.

A5.8.7.1.5. Type of opening. Where physical access is required, the following practices shall be followed in order of preference: a. An opening with no cover unless this is likely to degrade system performance, safety, or NBC contamination survivability. b. A hand operated (latched, sliding, or hinged) cap or door where dirt, moisture, or other foreign materials might otherwise create a problem. c. A quick-opening cover plate using ¼ turn captive fasteners if a cap will not meet stress requirements or space prevents a hinged cover. d. A screw-down cover, when captive fasteners cannot be used because of stress, structure, or pressurization constraints. Use minimum number of interchangeable screws to fasten door.

A5.8.7.2. Whole body access. Where whole body access is required, the opening shall accommodate 95% of projected maintenance.

A5.8.7.3. Access cover attachment. Covers shall be attached with the fewest number of simplest-to-operate fasteners practicable. Fasteners shall be operable by hand or by common hand tools in that order of preference. Small, removable covers shall be attached to the structure or otherwise retained to prevent loss.

#### A5.8.8. Fasteners.

A5.8.8.1. General. The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressurization, shielding, thermal, and safety requirements. When more than one size or type fastener is used on the same equipment or cover, the fasteners-equipment-cover interface shall permit the maintainer to readily distinguish the intended location of

each fastener. Finger or hand-operated fasteners shall be used when consistent with these requirements. Fasteners requiring non-standard tools shall not be used.

A5.8.8.2. Hinges and tongue-and-slot catches. Hinges, tongue-and-slot catches and mounting pins shall be used to minimize the number of fasteners required.

A5.8.8.3. Captive fasteners. Captive fasteners shall be used where dropping or losing such items could cause damage to equipment or create a difficult or hazardous removal problem. Captive fasteners shall also be provided for access covers requiring frequent removal.

A5.8.8.4. Quantity. If a hinged access panel or quick-opening fasteners will not meet stress or safety requirements, the minimum number of fasteners consistent with these requirements shall be used.

A5.8.8.5. Fastener head type.

A5.8.8.5.1. High-torque fasteners. External hex or external double-hex wrenching elements shall be provided on all machine screws, bolts or other fasteners requiring more than 14 N•m (10 lbf•ft) of torque. When external wrenching fasteners cannot meet the mechanical function or personnel safety requirements, or in limited access situations, and where use is protected from accumulation of foreign material, internal wrenching fasteners may be used. Direct tool access shall be provided to allow for torquing without the use of irregular extensions.

A5.8.8.5.2. Low-torque fasteners. External-hex wrenching head, internal-hex wrenching head, combination head (internal-hex or straight recess and external-hex wrenching head), or Torq-set fasteners, should be provided where less than 14 N•m (10 lbf•ft) torque is required. Internal-wrenching fasteners shall be provided only where a straight, or convex, smooth surface is required for mechanical function or personnel safety, and where use is protected from accumulation of foreign material (e.g., ice, snow). Straight-slot or cross-recess type internal grip fasteners shall not be provided, except as wood fasteners or where these type fasteners are provided on standard commercial items.

A5.8.8.5.3. Common fasteners. Whenever possible, identical screw and bolt heads shall be provided to allow panels and components to be removed with one tool. Combination bolt heads such as slotted hex head should be selected whenever feasible. Identical fasteners shall not be used where removal of wrong fastener can result in equipment damage or change to calibration settings.

A5.8.8.6. Accessibility. The heads of mounting bolts and fasteners should be located on surfaces readily accessible to the maintainer. Both hand and tool access shall be provided to the unthreaded or loosened fastener.

A5.8.8.7. Number of turns. Fasteners for mounting assemblies and subassemblies shall require a minimum number of turns, compatible with stress, alignment, positioning, and load considerations. When machine screws or bolts are required, the number of turns and the amount of torque shall be no more than necessary to provide the required strength except when a common fastener is utilized. All items requiring removal for daily or more frequently scheduled inspections and servicing shall use quick release fasteners.

A5.8.9. Attachments. Connected appurtenances, accessories, cables, hoses, and similar items shall not interfere with removing, replacing, or carrying an item. If such connected appurtenances interfere with these tasks, they shall be easily removed or disconnected from the equipment before